Clark County
Hydrology Monitoring Project
Quality Assurance Project Plan

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Prepared by:
Clark County Public Works Water Resources

Project Name: Clark County Hydrology Monitoring Project

Project Code: CCHMP

Agency Name: Clark County Washington

Agency Contact: Rod Swanson

Department: Public Works Water Resources

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Clark County Hydrology Monitoring Project
Quality Assurance Project Plan

Purpose of the Quality Assurance Project Plan

Clark County Public Works Water Resources (Water Resources) follows the general Quality Assurance Project Plan (QAPP) format defined by the State of Washington Department of Ecology (Ecology) (Lombard and Kirchmer, 2001). Water Resources requires a QAPP for each monitoring project. This plan addresses the Clark County Hydrology Monitoring Project's (CCHMP) design, schedule, methods of data collection and management, quality assurance and quality control requirements, data analysis, and reporting as they relate to both precipitation and flow monitoring gages owned or operated by Clark County.

Background and Problem Statement

Clark County's rapid population growth over the past two decades has significantly changed its predominant land uses and most likely impacted both the water quality and quantity of its streams, rivers, and lakes. This recent population increase required a state-issued NPDES permit in 1999 to help address growth-related stormwater runoff impacts.

Clark County has developed and is implementing an NPDES Stormwater Management Program to comprehensively address those impacts. In 2000, Clark County instituted the Clean Water Fee, which provides ongoing funding for expanded implementation of the county's NPDES Stormwater Management Program. Monitoring both water quality and quantity is a critical component of the expanded implementation because it helps assess past and current impacts as well as potential future management options.

Hydrological information is fundamental for the assessment and management of stormwater runoff impacts. Both precipitation and stream flow data are needed to help understand and manage runoff impacts. The hydrologic data will be utilized for input, calibration, and verification of models to improve stormwater and watershed management, including capital planning and stream protection and rehabilitation. Additionally, the hydrological information is being acquired and shared in a coordinated fashion with the local, nonmunicipal water and electrical services provider, Clark Public Utilities, and supports other local water quality monitoring efforts.

Organization and Schedule

Project Staff

Water Resources activities are administered through Clark County Public Works as part of the county's NPDES Stormwater Management Program.

Client:	Earl Rowell, Water Resources Manager
Supervisor:	Earl Rowell, Water Resources Manager
Project Manager:	Rod Swanson, Water Resources Monitoring Supervisor
QA Coordinator:	Robert Hutton, Water Resources Scientist
Project Team:	Robert Hutton
	Rod Swanson

Jeff Schnabel
Ron Wierenga
Jason Wolf

Consultant Contracts

Portions of the CCHMP fieldwork and data summaries, primarily for the permanent stream and precipitation gages, are performed by River Measurement, LLC.

Hydrology:	River Measurement, LLC
Address:	4616 NW 122nd Street, Vancouver, WA 98685-2127
Phone:	360-571-2290
Contact:	Steve Gustafson, Principal Hydrologist

Budget

Budget estimates for the CCHMP are found in Table 1:

Budget Category	Estimated Cost (annual)
Staff	$28,000.00
Vehicle	$250.00
Consultant	$36,400.00
Total	**$64,650.00**

Table 1. Annual budget estimates for the Water Resources CCHMP.

Project Timeline

The CCHMP has an expected duration of at least five years. This timeframe is needed in order to collect sufficient data to calibrate and verify hydrological models as well as calculate hydrological indicators. It is possible that the project could be extended or shortened due to changing data needs. Provisional hydrological data will be collected from permanent gages and reviewed by consultant River Measurement, LLC at least six times during the first year of operation. This data will be submitted to Clark County periodically but will remain provisional until finalized after data has been collected for one year. Clark County staff will collect and review hydrological data from temporary project gages at least every other month for data entry and analysis. The scheduling and frequency of in-stream hydrological measurements will be dependent upon the timing of the relative stream stages needed to complete stage-discharge curves. Brief annual project reports including data and QC results will be produced by Water Resources beginning with the year 2003 report due in March 2004 as required in the grant agreement with Ecology.

Project Description

The intent of the CCHMP is to provide high-quality data and water quantity information for stormwater management and Clark County decision-makers. Within this context, data are used for a variety of purposes, including:

- Annual report of Clark County Hydrology
- Watershed and stormwater management by Clark County and other local entities

Objectives

Specific project objectives are to:

- Provide Clark County decision-makers and the general public with analytical information that helps describe water quantity across a range of sites throughout the County.
- Provide Clark County with timely, high-quality hydrological data that are comparable to those collected by other local and regional agencies (e.g., U.S.G.S., Ecology).
- Target water bodies for flow monitoring that are of manageable size for which Clark County has jurisdiction and can contribute to beneficial outcomes.
- Provide reliable flow data that accurately depicts base to flood flows
- Provide accurate representative precipitation data for Clark County.
- Provide accurate stream flow and precipitation data to calibrate watershed models for capital design and watershed management.
- Monitor flows of a local reference or control stream for estimating natural conditions.
- Enhance interpretation of water quality information and possible changes in stream habitats and channels over time.
- Build on the value of data from selected past hydrological monitoring sites by continuing to monitor at priority sites.
- Derive accurate stage – discharge rating curves from field measurements at various flows
- Calculate hydrological metrics such as daily mean, minimum, and maximum discharges

Sampling Design

Station Selection and Installation

The general vicinities of stream flow and precipitation measurement stations were selected to achieve several goals. An important goal was to have sites that would be representative of the broad range of stream flow and rain fall conditions found throughout Clark County to help address information needs and fill spatial data gaps. Additionally, several potential locations at or very near previous hydrological measurement sites were targeted because of their added value for data record continuity. The goal for several stream gages was to be very near long-term water quality monitoring sites to enhance interpretation of physical, chemical, and biological water quality data. Additionally, general locations would need to provide sufficient spatial and temporal input data for hydrological models. Other vicinity selection criteria included convenience of access from nearby public roads, long-term accessibility via public ownership or easements, and proximity to electrical power and telephone lines.

Subsequently, the general vicinities of proposed gaging locations were further refined to determine the best suited specific sites for collecting accurate stage, discharge, and precipitation data. River Measurements, LLC, a professional hydrology consulting firm, was contracted to refine the site scoping, make recommendations, then acquire and install needed hydrological monitoring equipment. Within the preferred general vicinities, the consultant evaluated specific locations for potential stream gaging and precipitation monitoring sites to help optimize data accuracy. Site specific criteria used for prospective stream gaging sites included channel stability, channel geometry, vegetation, potential for backwater, and accessibility. All of the resulting stream gaging sites were located in either streams or open channels without manmade control structures. Site specific criteria used for prospective precipitation gaging sites included security from vandals and avoiding biasing factors such as interception by nearby trees or unusual wind patterns.

After site selection, River Measurements, LLC upgraded existing or installed new site specific instrumentation and shelters (Appendix A: Clark County Hydrology Monitoring Sites Typical Equipment Configurations). All instrumentation was installed per manufacturers' recommendations to ensure optimal performance.

Figure 1 shows the locations of the fifteen stream flow and eight precipitation CCHMP monitoring stations. Table 2 contains station names and descriptions. Sites have been assigned station names consistent with Water Resources' county-wide naming conventions.

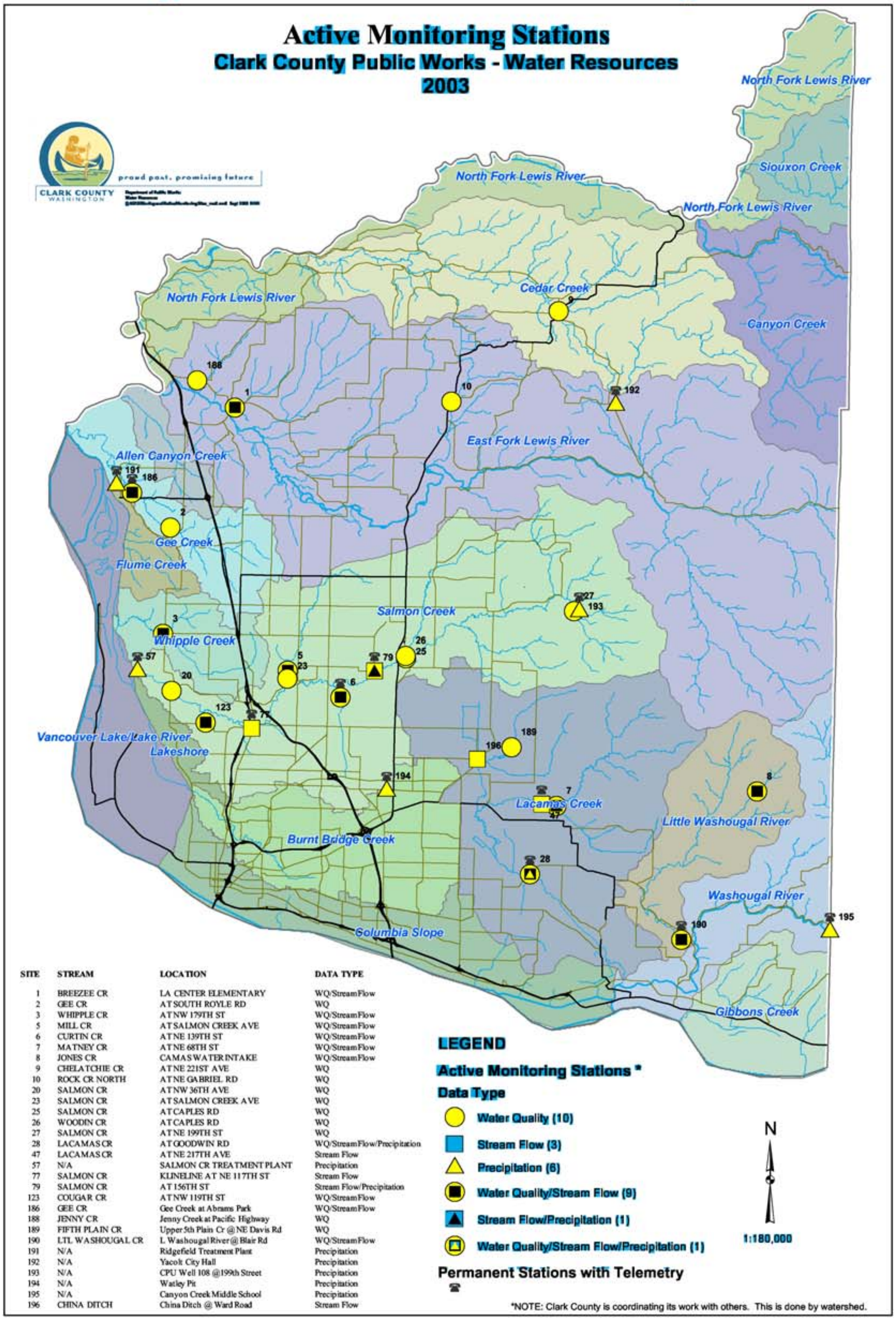
Table 2. Hydrology station names and locations for Water Resources CCHMP.

Flow / Rainfall	ID Code	Waterbody	Station Location Description	Township, Range, Section, ¼ Section	Temporary Project / Permanent Installation
Flow	BRZ008	Breeze Creek	Breeze Cr Upstream of LaCenter Btms Bridge	T4N,R1E,S3,NE	Temporary
Flow	CHD012	China Ditch	China Ditch Upstream of NE Ward Road	T2N, R3E, S6, NW	Temporary
Flow	CGR018	Cougar Creek	Cougar Cr at NW 119th Street	T3N,R1E,S28,SE	Temporary
Flow	CUR022	Curtin Creek	Curtin Cr at NE 139th Street	T3N,R2E,S20,SW	Permanent
Flow	GEE028	Gee Creek	Gee Cr at Abrams Park Bridge	T4N,R1E,S19,NW	Permanent
Flow	GEE052	Gee Creek	Gee Cr at Royle Road	T4N,R1E,S29,SE	Temporary
Flow	JNS058	Jones Creek	Jones Cr Upstream of Camas Water Intake	T2N,R4E,S3,SE	Temporary
Flow	LAC050	Lacamas Creek	Lacamas Cr at Goodwin Road	T2N,R3E,S20,SE	Permanent
Flow	LAC080	Lacamas Creek	Lacamas Cr at NE 217th Avenue	T2N,R3E,S9,NW	Permanent
Flow	LWG013	Little Washougal	Little Washougal R at SE Blair Road	T2N,R4E,S32,SW	Permanent
Flow	MAT008	Matney Creek	Matney Cr at NE 68th Street	T2N,R3E,S9,SE	Temporary
Flow	MIL008	Mill Creek	Mill Cr at Salmon Creek Avenue	T3N,R1E,S24,NE	Temporary

Flow	SMN020	Salmon Creek	Salmon Cr at Klineline Footbridge	T3N,R1E,S35,NW	Permanent
Flow	SMN045	Salmon Creek	Salmon Cr at NE 156th Street	T3N,R2E,S21,NE	Permanent
Flow	WPL048	Whipple Creek	Whipple Cr at NW 179th Street	T3N,R1E,S17,NW	Temporary
Rainfall	CAPHRN	n/a	Cape Horn School	T2N,R5E,S31,SE	Permanent
Rainfall	LAC050	n/a	Lacamas Cr at Goodwin Road	T2N,R3E,S20,SE	Permanent
Rainfall	ORCHRDS	n/a	Near Gate at Whatley Pit	T2N,R2E,S10,NW	Permanent
Rainfall	RDGFLD	n/a	Ridgefield Treatment Plant	T4N,R1W,S24,NE	Permanent
Rainfall	SMN045	n/a	Salmon Cr at NE 156th Street	T3N,R2E,S21,NE	Permanent
Rainfall	SNCRTP	n/a	On roof at Salmon Creek Treatment Plant	T3N,R1E,S19,NE	Permanent
Rainfall	VNRSBRG	n/a	CPU Well 108 24000 block of 199th St	T3N,R3E,S3,SW	Permanent
Rainfall	YACOLT	n/a	Yacolt Town Hall	T4N,R3E,S2,NW	Permanent

Table 2. Hydrology station names and locations for Water Resources CCHMP (continued).

Figure 1. Location of the CCHMP Monitoring Sites



SITE	STREAM	LOCATION	DATA TYPE
1	BREEZEE CR	LA CENTER ELEMENTARY	WQ/StreamFlow
2	GEE CR	AT SOUTH ROYLE RD	WQ
3	WHIPPLE CR	AT NW 179TH ST	WQ/StreamFlow
5	MILL CR	AT SALMON CREEK AVE	WQ/StreamFlow
6	CURTIN CR	AT NE 139TH ST	WQ/StreamFlow
7	MATNEY CR	AT NE 68TH ST	WQ/StreamFlow
8	JONES CR	CAMAS WATER INTAKE	WQ/StreamFlow
9	CHELATCHIE CR	AT NE 221ST AVE	WQ
10	ROCK CR NORTH	AT NE GABRIEL RD	WQ
20	SALMON CR	AT NW 36TH AVE	WQ
23	SALMON CR	AT SALMON CREEK AVE	WQ
25	SALMON CR	AT CAPLES RD	WQ
26	WOODIN CR	AT CAPLES RD	WQ
27	SALMON CR	AT NE 199TH ST	WQ
28	LACAMAS CR	AT GOODWIN RD	WQ/StreamFlow/Precipitation
47	LACAMAS CR	AT NE 217TH AVE	Stream Flow
57	N/A	SALMON CR TREATMENT PLANT	Precipitation
77	SALMON CR	KLINELINE AT NE 117TH ST	Stream Flow
79	SALMON CR	AT 156TH ST	Stream Flow/Precipitation
123	COUGAR CR	AT NW 119TH ST	WQ/StreamFlow
186	GEE CR	Gee Creek at Abrams Park	WQ/StreamFlow
188	JENNY CR	Jenny Creek at Pacific Highway	WQ
189	FIFTH PLAIN CR	Upper 5th Plain Cr @ NE Davis Rd	WQ
190	LTL WASHOUGAL CR	L Washougal River @ Blair Rd	WQ/StreamFlow
191	N/A	Ridgefield Treatment Plant	Precipitation
192	N/A	Yacolt City Hall	Precipitation
193	N/A	CPU Well 108 @199th Street	Precipitation
194	N/A	Watley Pit	Precipitation
195	N/A	Canyon Creek Middle School	Precipitation
196	CHINA DITCH	China Ditch @ Ward Road	Stream Flow

Monitoring Schedule
The field monitoring schedule for both flow and precipitation measurements will vary depending on instrumentation at the sites but will follow the general pattern summarized in Table 3. The permanent installation and temporary project flow monitoring sites will initially be visited at least six times per year for discharge measurements, downloading digitally logged stage data, and maintaining instrumentation. The frequency of site visits for discharge measurements may need to be increased to ensure documentation of stage-discharge relationships over a wide range of flows. The number of site visits to the permanent flow monitoring sites may be reduced after telemetry is fully operational and stage-discharge relationships have been established. The frequency of site visits to the temporary project flow monitoring sites will typically be every other month after stage-discharge relationships have been established. The permanent precipitation monitoring sites will also be visited at least six times per year for downloading digitally logged data and maintaining equipment. Additional site visits will be made to address issues such as those that could result from flooding.

Timeframe	Monitoring Station	Frequency	Duties
First year of operation	Permanent and temporary flow monitoring sites	At least 6 times per year to establish stage-discharge relationships	Measure stage and discharge, download data, and maintain equipment
First year of operation	Permanent precipitation monitoring sites	At least 6 times per year	Download data, and maintain equipment
After first year of operation	Permanent flow monitoring sites	Typically every other month after telemetry is operational	Measure stage, and maintain equipment
After first year of operation	Temporary flow monitoring sites	Typically every other month	Measure stage, download data, and maintain equipment
After first year of operation	Permanent precipitation monitoring sites	Typically every other month after telemetry is operational	Maintain equipment

Table 3. Water quantity field monitoring schedule for the CCHMP.

Representativeness
CCHMP data are intended to be representative of conditions at each monitoring station. Water Resources utilizes standard monitoring procedures which are designed to facilitate the collection of representative hydrological data. Hydrological measurements and data acquisition will be performed according to standard procedures developed by the United States Geologic Survey (U.S.G.S.) (United States Department of Interior, 1982). For example, measuring discharge in the field using a calibrated current meter at acceptable stream cross-section widths and depths will help ensure representative measurements.

The frequency of automated measurements is designed to capture all important variations in flow and precipitation. Automated stage recordings will be taken at 15-minute intervals to compute flow variations. Precipitation recordings are triggered by 0.01 inches of rain to ensure precise rainfall measurements over specific timeframes. Discharge rating curves will be constructed using a minimum of six field discharge measurements to provide representativeness across the full range of potential flows.

Data Comparability

One of the objectives of the CCHMP is to gather data that are comparable to other local and regional data. Long-term comparability of CCHMP data with other data is facilitated by utilizing and documenting standard procedures for data collection and analyses.

The CCHMP utilizes the nationally recognized standard procedures followed by the U.S.G.S. As such, the CCHMP results should be directly comparable with those of other agencies that follow accepted U.S.G.S. protocols for discharge and precipitation measurements. At those CCHMP sites with previous Clark County flow and precipitation monitoring, a case by case review will need to be made regarding the usefulness of earlier measurements.

Quality Objectives

Measurement Quality Objectives

Characteristics, methods or equipment, reporting resolution, and accuracies are listed in Table 4. Measurement Quality Objectives (MQOs) for the CCHMP are set at generally accepted U.S.G.S. targets for hydrological monitoring projects. Measurements follow standard procedures designed to reduce most sources of bias by adherence to the methods listed in Table 4. Field measurements and data management employ quality control procedures appropriate to the characteristic being evaluated. It is generally assumed that discharge estimates will be less accurate at low flows than at higher flows in terms of the percentage of their total flow.

Table 4. CCHMP characteristics, methods, reporting and accuracy limits.

Characteristic	Method / Equipment	Reporting Limit	Accuracy	Reference
		Units	Units or % error	
Precipitation (both rainfall volume and rate) - automated	Tipping Bucket (Sutron model 5600-0420-1 gage calibrated to tip for each 0.01 inch collected, mercury switch initiates signal to accumulating device, 8.24 inch diameter orifice, temperature range 0 to 60 degree Celsius)	0.01 inches	Within 2% at 2 inches / hr	Sutron Corp. Tipping Bucket Rain Gage Manual
Data Recording and Telemetry - automated	Digital Data Logger, I/O Modules, and Modem (Sutron model 9210-0000-1 Xlite data logger, Sutron I/O modules, and Sutron model 8080-0005-1 Voice Modem)	Sensor dependent (e.g. 12.34 ft)	Logger clock 0.01% or 2 seconds per day accuracy at -20 to 60 degrees Celsius	Sutron Xpert Operations and Maintenance Manual, Sutron Voice Modem Operation Manual
Stage – automated	Stage Sensor – Nonsubmersible pressure transducer or bubble gage (Sutron Accububble model 5600-0131 connected to Sutron Accubar pressure transducer)	0.0001 psi (sensor input) or 0.01 feet of water depth (default digital sensor output)	±0.01 feet for water up to 10 feet deep, 0.1% of reading for water 10 to 50 feet deep, full temperature compensation from -25 to 60 degrees Celsius	Sutron Accububble Self Contained Bubbler System Operations and Maintenance Manual

Characteristic	Method / Equipment	Reporting Limit	Accuracy	Reference
		Units	Units or % error	
Stage / Water Temperature - automated	Stage and Temperature Sensors – submersible pressure transducer (Design Analysis model H-310-15 with integrated pressure transducer and Therm-X water temperature probe)	Pressure: 0.0004%, or output of 0.01 feet Temperature: 0.0004%, or output of 0.1 degrees Celsius	Pressure: ±0.007 feet or less than 0.02% error in measurement for water 0 to 34.60 feet deep, Temperature: ± 1 degree Celsius over 0 to 40 degrees Celsius	Design Analysis Associates, Inc. Water Log Series Model H-310 Owner's Manual
Stage / Water Temperature/ Data Recording - automated	Stage and Temperature Sensors – submersible pressure transducer, temperature probe, and data logger (Design Analysis model DH-21-15 with an integrated data logger)	Displayed output resolution: Pressure: 0.0001psi or 0.01 feet Temperature: 0.1 degrees Celsius	Pressure: ±0.017 feet or less than 0.05% error in measurement for water 0 to 34.60 feet deep, Temperature: ± 1 degree Celsius over 0 to 40 degrees Celsius	Design Analysis Associates, Inc. Water Log Series Model DH-21 Owner's Manual
Stage – manual	Electric – Tape Stage Gage (Rickly Hydrological – electric tape gage Style A)	0.01 feet	± 0.01 feet	Measurement and Computation of Streamflow: Vol. 1 Measurement of Stage and Discharge
Stage – manual	Wire-weight Stage Gage (Type A wire-weight gage)	0.01 feet	± 0.01 feet at calm and ± 0.10 feet at turbulent water surfaces	Measurement and Computation of Streamflow: Vol. 1 Measurement of Stage and Discharge
Stage – manual	Staff Gage (Rickly Hydrological Staff Plates, standard U.S.G.S. vertical type)	0.02 feet graduations / 0.01 feet	± 0.01 feet at calm and ± 0.10 feet at turbulent water surfaces	Measurement and Computation of Streamflow: Vol. 1 Measurement of Stage and Discharge
Stage – Physical mark	Crest-stage Gage (standard U.S.G.S. type with a graduated wooden staff in a 2-inch galvanized pipe)	0.02 feet	± 0.01 feet	Measurement and Computation of Streamflow: Vol. 1 Measurement of Stage and Discharge
Discharge – manual	Discharge by Conventional Current-meter Method (Price Pygmy current meter and Aquacalc discharge meter and computer)	0.01 cubic feet per second	The standard error of the measurements is such that errors of 2/3 of the measured discharges would be less than 2.2%	Measurement and Computation of Streamflow: Vol. 1 Measurement of Stage and Discharge

Table 4. CCHMP characteristics, methods, reporting and accuracy limits (continued).

Field Procedures

CCHMP protocols used for field discharge measurement equipment calibration, field methods, data management, and quality assurance, as well as general considerations are described in detail in Appendix B: Standard Procedures for Monitoring Activities: Clark County Water Resources Section, ***Stream Discharge Measurements***. Most of these protocols are based on the U.S.G.S. publications, Measurement and Computation of Streamflow: Volumes 1 and 2 (U.S.D.I., 1982).

River Measurements, LLC, is under contract for development of stage-discharge rating curves for the permanent stream flow monitoring stations and their operation and maintenance as well as those of the precipitation monitoring stations. Additionally, River Measurements, LLC will measure stage and discharge from secure bridge sites for rating curve development during high flow periods at the temporary project stream flow monitoring stations. These higher flows preclude County staff from measuring discharge using the stream wading method. They will require the use of either a handline or sounding reel supported by a bridgeboard to suspend the current meter and sounding weight from bridges. Except for these higher flow measurements, Clark County staff will develop all the temporary projects' rating curves and provide operation and maintenance.

Typically, manual discharge measurements are conducted by at least 2-person field crews following standard operating procedures. Multi-person crews are utilized for safety, efficiency, and quality assurance confirmation.

Checklists and logs are kept for all field activities. Appendix C: Discharge Measurement Checklist, shows detailed information for typical field equipment for wadeable conditions. Logs may consist of standardized field sheets (Appendix D: Stream Discharge Measurement Datasheet) as well as bound log books containing ancillary data and observations. Logs are waterproof and entries are made with pencil or indelible ink. Corrections are made by drawing a single line through the error such that it remains legible, writing the correction adjacent to the error, and initialing the correction. Records are cross-checked for consistency between data sheets, field logs, and other relevant data. Log books are archived in Water Resources files.

Quality Control

Field QC

Standard quality control procedures are used for field discharge and precipitation measurements. This includes keeping all components of the gaging stations in proper working order.

Installation and calibration of all automated stage and precipitation gage recording stations are generally done according to accepted U.S.G.S. standard operating procedures (U.S.D.I., 1982, Vol. 1). Automated stage and precipitation sensors are certified to be calibrated and validated with instruments traceable to the National Institute of Standards and Technology (NIST) (Appendix E: Example Certificate of Calibration for WaterLog Series DH-21 Stage and Temperature Sensor).

Inspection and maintenance of all precipitation and field discharge measurement equipment will be done either prior to or during field visits. Precipitation monitoring stations are inspected and cleaned, as needed, during field visits. Current meters are visually inspected and cleaned, if needed, before field work. Spin and count tests are performed on current meters before their use. Meters and other equipment are assembled, calibrated and maintained in accordance with the manufacturer's instructions (JBS Instruments, undated). These activities are used to help ensure that field instruments are attaining stated accuracy and resolution specifications.

The accuracy of the current meters used is dependent on the relative velocity and will impact recorded values. The reliable range of velocity measurements for the Price Pygmy current meter is from 0.2 to 3 feet per second (Fulford, 2001). Its accuracy, expressed as a percent of velocity, is from +/- 6% to +/-1.5% at velocities ranging from 0.25 to greater than or equal to 2.2 feet per second, respectively. The reliable velocity range of the Price Type-AA is from 0.1 to greater than 20 feet per second. Its accuracy is from +/- 6% to +/-1.1% at velocities ranging from 0.25 to greater than or equal to 2.2 feet per second, respectively. Velocity measurements are recorded to the nearest 0.01 feet per second and discharge calculations are reported to the nearest 0.1 cubic feet per second. Factors that may detrimentally affect field discharge or precipitation measurements are noted on field sheets to help interpret calculated estimates.

To allow comparisons and to maintain reliability, all recording stream discharge sites have sturdy reference gages, nearby reference marks, and crest-stage gages. The reference gage, the base gage to which each station's recording instruments are set, covers the entire range of expected stages. Outside staff reference gages are used for sites without stilling wells. Sites with stilling wells utilize inside electric-tape reference gages within the wells. During field visits, the automated stage recorder's latest stage reading is compared to the current water surface level at the reference gage to ensure all instrumentation is working properly. At higher, more turbulent flows the latest data logger reading may differ by more than 0.02 feet from that of the reference gage. However, at low flows this difference would potentially require corrective action. All sites have three nearby reference marks, permanent points of known gage-height elevation that are independent of the gage structure, surveyed to the gage datum. Gages are periodically checked by running levels to their reference marks. All sites have crest-stage gages to mark high-water levels for information backup in case of equipment failure or to mark stage peaks between automated data recordings.

Replicate velocity measurements are also made on 10 % of subsections within transects and entire transect replicates are periodically done throughout the field season. On the average, using the two point method of estimating mean vertical velocity gives results that are within 1 % of the true mean velocity in the vertical (U.S.D.I., 1982, Vol. 1).

Corrective Actions

Data quality problems encountered during the measurement and calculation of discharge and precipitation are addressed as needed. Generally, this could involve analysis of QC measurements, re-calibration of equipment, modifications to the field procedures, increased staff training, or by qualifying results appropriately.

In the office, discharge and precipitation are estimated and possibly refined utilizing recorded data, field measurements, and field notes. The discharge estimates are based on periodically updated stage-discharge rating curves. These curves are derived from field discharge measurements and reference gage readings. These stage-discharge relationships are checked regularly and especially after floods. The updating of stage-discharge curves are based on new data points sufficiently outside the existing curve or when streambed changes are suspected at automated stage recording sites. Occasionally, other corrective actions may be needed such as a stage datum correction to a station's stage record and recalibration of its stage logger's offset.

This would apply if there are consistent differences averaging 0.02 feet or more over several months between concurrent logged stage values and their reference gage field readings. Other equipment problems may lead to adjustments in estimates. For example, a failure of a precipitation gage would be investigated, corrected, and documented for future adjustments to the data record. These adjustments could include a weighted estimate of precipitation for the resulting data gap using data from other nearby precipitation monitoring stations.

Corrective actions may also be done during field work. When replicate discharge subsection values differ substantially from their original values, a field evaluation is made and the entire transect may be redone. Additionally, during periods of rapidly changing stage conventional field procedures may be abbreviated to expedite the acquisition of as consistent and representative data as possible. This may be achieved by reducing the number of cross section observation verticals from approximately twenty down to six to ten, taking only one velocity measurement per vertical, and reading nearby staff gages at every third velocity measurement. Any rapid change in stage and abbreviated procedures would also be noted on the field sheets. Another field corrective action would occur if debris is observed interfering with stage or precipitation gages. The character of the debris and its probable impact would be evaluated, corrected if needed, and noted in the field note book for further interpretation during data evaluation.

Downloaded or telemetered data are quickly organized and reviewed for completeness and reasonableness. This will help identify anomalous readings indicating problems with gaging station equipment or other issues affecting results. Documentation of any needed corrective actions may include problem identification, investigation procedures, corrective action taken, and effectiveness of the corrective action.

Data Management Procedures

CCHMP data and field notes are recorded or retrieved, stored, and managed in both hardcopy and digital form at Water Resources. Raw field discharge measurement data and field notes are recorded on field data sheets which are organized and archived in binders. Applicable data are entered into spreadsheets for summary statistic calculations including total instantaneous discharge. River Measurement, LLC, and the QA coordinator / project manager are responsible for validating and cross-checking data entry and explaining any necessary data qualifiers. Entered field data and calculated summary statistics are digitally copied, reorganized and password protected. Summary statistics are copied into a secure central relational database for long-term storage, retrieval, and analysis. Alternatively, automated stream stage and precipitation measurements are digitally recorded on data loggers and then either downloaded in the field or telemetered from the field gaging sites onto computers for data storage. Stream discharge is later computed in the office for every 15 minute stage value. Provisional mean, minimum, and maximum daily discharge are also calculated then finalized at the end of the year. Calculated discharge and precipitation estimates from the automated gaging stations are also copied into the secure central relational database similar to manual discharge measurement results.

Audits and Reports

Audits

River Measurement, LLC and the project manager / QA coordinator periodically review the field data, methods, and data management activities to make an assessment of the program and identify corrective actions or method revisions.

Reports

Annual data summaries compiled by Water Resources address project methods, summarize data accuracy and completeness, describe any significant data quality problems, and suggest modifications for future monitoring. Reports are peer reviewed by Water Resources staff. CCHMP summaries are generally incorporated as attachments to the county's annual NPDES permit compliance report to Ecology. Executive summaries, and full reports as warranted, are placed on the county's website to facilitate dissemination of information to the public.

The hydrological data will be utilized for watershed planning and capital facilities project designs. Differences between watersheds and portions of them will be evaluated. The data will be used for input to nationally recognized mathematical water resource models. For example, the data will be used to help develop regional design equations for capital projects.

Data Review, Verification, and Validation

During each monitoring trip, field crews review field logs to confirm that all necessary field measurements have been collected. Field results are reviewed, verified, and documented by field staff in data reports to Water Resources. Upon receipt, contracted hydrological data are reviewed for errors, omissions, and data qualifiers prior to data entry.

Data verification involves examination of results collected during the project to provide an indication of whether the reporting limits, precision, bias, and accuracy Measurement Quality Objectives have been met. To evaluate whether the target for reporting limits has been met, results will be examined to determine if any of the values do not meet the required resolution or reporting limits. To evaluate whether precision targets have been met, pairs of duplicate discharge measurement QC results are compared by estimating their relative standard deviation (RSD). The RSD is calculated by dividing the duplicates' standard deviation by their respective mean discharge. Converted to a percent of the mean, it is used to judge whether the %RSD precision target has been met. Generally, for CCHMP discharge estimates this target is 5%.

Since the true discharge of a stream cross section is unknown, the statistical analysis of bias and accuracy is not possible as calculated when comparing laboratory results of check standards and matrix spikes of known concentrations. Bias (systematic error) will be kept to a minimum by careful adherence to CCHMP standard operating procedures. Additionally, the U.S.G.S. has reported earlier study findings showing that, on average, reliable results can be achieved if standard methods in the U.S.G.S. Measurement and Computation of Streamflow: Volume 1. Measurement of Stage and Discharge manual are followed (Rantz, 1982, Vol. 1). Specifically, on the average when estimating a stream's current, both the six-tenths depth and the two-point (average of 0.2 and 0.8 depth velocities) methods give results that are approximately within 1% of the true mean velocity for a stream subsection's vertical. Additionally, if single discharge measurements were made at a number of gaging sites using the same standard methods, the errors of two thirds of the measured discharges would be less than 2.2%. Using a blind comparison, the Washington State Department of Ecology (D.O.E.) has reported very high correlations (r^2>.98) between instantaneous discharge measurements by their Stream Hydrology Unit and discharge estimates from historical U.S.G.S. discharge rating curves (D.O.E., 2003, *SHU home web page*).

CCHMP discharge measurement methods are very similar to those of the D.O.E. (D.O.E., 2003, *SHU Standard Operating Procedures web page*) and the U.S.G.S. However, since many of the discharge sites monitored by CCHMP are fairly small streams it is assumed that their accuracy level will be somewhat lower than those indicated above. On average, the CCHMP's discharge estimates are assumed to be approximately within 5% of the true flow except under very low flow conditions when their accuracy would probably be closer to within 10% of the true discharge. Since CCHMP's Standard Procedures are very similar to those of both the U.S.G.S. and D.O.E., it is assumed that the project's Measurement Quality Objectives will be met at the above accuracy levels of the U.S.G.S. except as noted.

Data validation consists of a detailed examination of the complete data package using professional judgment to assess whether the procedures in the Standard Procedures and QAPP have been followed. Data validation is performed by River Measurement, LLC and the project manager / QA coordinator during the preparation of annual reports.

Data Quality Assessment

Taking into account the results of data review, verification, and validation, an assessment will be made as to whether the data are of sufficient quality to attain project objectives.

References

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Appendices

APPENDIX A: Clark County Hydrological Monitoring Sites Typical Equipment Configurations

Permanent Telemetered Stream Stage Recording Sites

Instrument Shelters

Four foot diameter heavy gage corrugated steel pipe stilling well
Grafton Fabricating heavy duty gage steel look-in type instrument shelter

Automated Stage and Temperature Sensors and Data Loggers

Sutron data logger (model 9210 XLite) with phone modem (model 8080-0005-1) for telemetry
Design Analysis submersible type pressure transducer stage sensor (model H-310-15)
Sutron bubble gage type stage sensor for nonsubmersible sites (model 5600-0131)
Therm-X integrated temperature sensor with Sutron adaptor
AC electric power and telephone line hookups
Uni-Solar 21-watt vandal resistant solar panel with regulator
12-Volt DC battery, battery float charger, surge protector

Stilling Wells Reference Gages

Rickly Hydrological Electric tape gages

Stream Staff Reference Gages

Rickly Hydrological U.S.G.S. type staff plates with 0.01 foot increments

Stream Crest Stage Gages

U.S.G.S. Standard floating ground cork type contained in 2 inch diameter galvanized steel pipe

Temporary Project Non-telemetered Stream Stage Recording Sites

Instrument Shelters

All instrumentation is housed in accessible 2 inch diameter secure capped galvanized steel pipes

Automated Stage and Temperature Sensors and Data Loggers

Design Analysis data logger and sensor (model DH-21-15)
- Integrated data logger
- Integrated submersible type pressure transducer stage sensor
- Integrated water temperature sensor

Stream Staff Reference Gages

Rickly Hydrological U.S.G.S. type staff plates with 0.01 foot increments

Stream Crest Stage Gages

U.S.G.S. Standard floating ground cork type contained in 2 inch diameter galvanized steel pipe

Permanent Telemetered Precipitation Recording Sites

Instrument Shelters

Enclosures are dependent on site:
Four foot diameter heavy gage corrugated steel pipe stilling well
Weather proof and vandal resistant enclosures for data loggers

Automated Precipitation Sensors and Data Loggers

Sutron data logger (model 9210 XLite) with phone modem (model 8080-0005-1) for telemetry
Sutron tipping bucket rain gage (model 5600-0420)
Therm-X air temperature probe with Sutron adaptor
Electrical power and telemetry options dependent on site:
- AC electric power and telephone line hookups
- Mobile phone telemetry
- Uni-Solar 21-watt vandal resistant solar panel with regulator
- 12-Volt DC battery, battery float charger, surge protector

APPENDIX B:
Standard Procedures for Monitoring Activities: Clark County Water Resources Section, Stream Discharge Measurements (DRAFT)

Stream Discharge Measurements

Primary References: Rantz, SE, and others, 1982. Measurement and computation of streamflow: Vol. 1 and 2, USGS Water Supply Paper 2175.

Procedure Application: Measuring water velocity, depth, and channel width for calculating stream discharge; velocity is measured with the Price Pygmy current meter when the average depth of the cross section is 1.5 ft or less.

Instrument(s): Price Pygmy velocity meter
AquaCalc 5000 Streamflow Computer

Range: 0.2 to 3 ft/s
Resolution: 0.01 ft/s
Accuracy: (varies with velocity see Fulford, 2001)

Equipment:
- Price USGS type Pygmy current meter
- Price USGS type AA current meter
- AquaCalc model 5000 Open Channel Flow Computer
- top setting wading rod
- 15', 50', 200', and 300' weighted or fiberglass measuring tapes
- safety rope, lifejackets, and safety vests
- stakes and hammer
- surveyor's measuring rod
- notebook/datasheets/aluminum clipboard
- wading boots/chest waders
- bridge board or crane and counterweights
- Type A or B Reel for suspending Type AA current meter and weights
- Columbus-type sounding weights (30, 50, 75, and 100 pounds)
- sounding weight hanger bars and pins
- Lineman Pliers (emergency cutting of sounding line)
- tool box with small screwdriver

Meter Calibration/preparation:

Principle of operation of the current meter: The Pygmy current meter consists of a set of cups (the bucket-wheel) that rotate horizontally on a sharply pointed pivot as flowing water drags across the cups. A sensor in the upper arm or yoke of the meter detects the rotation of the bucket-wheel through a magnet mounted in its upper shaft. The meter is calibrated such that if the number of revolutions of the cups in a certain time is known, then the linear velocity of the water can be determined. The USGS has established rating tables relating rotations to velocity by calibrating these meters. Field personnel must be knowledgeable about the meter's basic components and operation to ensure its function.

Selection of current meter based on depth and velocity: Water Resources has both a Pygmy and Price AA current meter. As general rule, if there are shallow sections of the transect less than 0.5 ft or the average depth is less than or equal to 1.5 ft the Pygmy current meter should be used. Furthermore, the water velocity in the transect should not exceed the range of the Pygmy meter, which has a maximum of 3 ft/s. Situations where the average depth is greater than 1.5 ft or velocity is greater than 3 ft/s dictate the use of the Price AA meter. The following table is provided to clarify meter selection and depth from water surface for velocity measurement.

Table 5. Current Meter Selection Criteria.

Meter Type	Velocity Range*	Approx. Depth Range˜	Velocity Method˜ (From Surface)
Price Pygmy	0.2 ft/sec to 3 ft/sec	0.3 ft to 1.5 ft	0.6
Price AA	0.1 ft/sec to > 20 ft/sec	1.5 ft to < 2.5 ft	0.6
Price AA	0.1 ft/sec to > 20 ft/sec	2.5 ft or >	0.2 and 0.8

* Fulford, 2001; ˜ Rantz, 1982, Vol. 1.

Measurement:

Theory: The midsection method determines discharge by dividing a stream cross section into many subsections, and then summing the products of the measured subsection areas and their respective average velocities (Figure 1) (see equations below). The overall goal of measurement is obtaining enough width, depth, and velocity data to accurately characterize the cross-section.

$$\textbf{\textit{Mid-subsection discharge}}\ (q_n) = v_n\left[\,1/2\left(b_{(n+1)} - b_{(n-1)}\right)\right] d_n$$

$$\textbf{\textit{End-subsection discharge}}\ (q_n) = v_n\left[\,1/2\left(b_{(n+1)} - b_{(n)}\right)\right] d_n$$

Where: V_n = mean velocity at vertical x, b_n = distance from initial point to vertical x, $b_{(n-1)}$ = distance from initial point to preceding vertical, $b_{(n+1)}$ =distance from initial point to next vertical, and d_n = depth of water at vertical x.

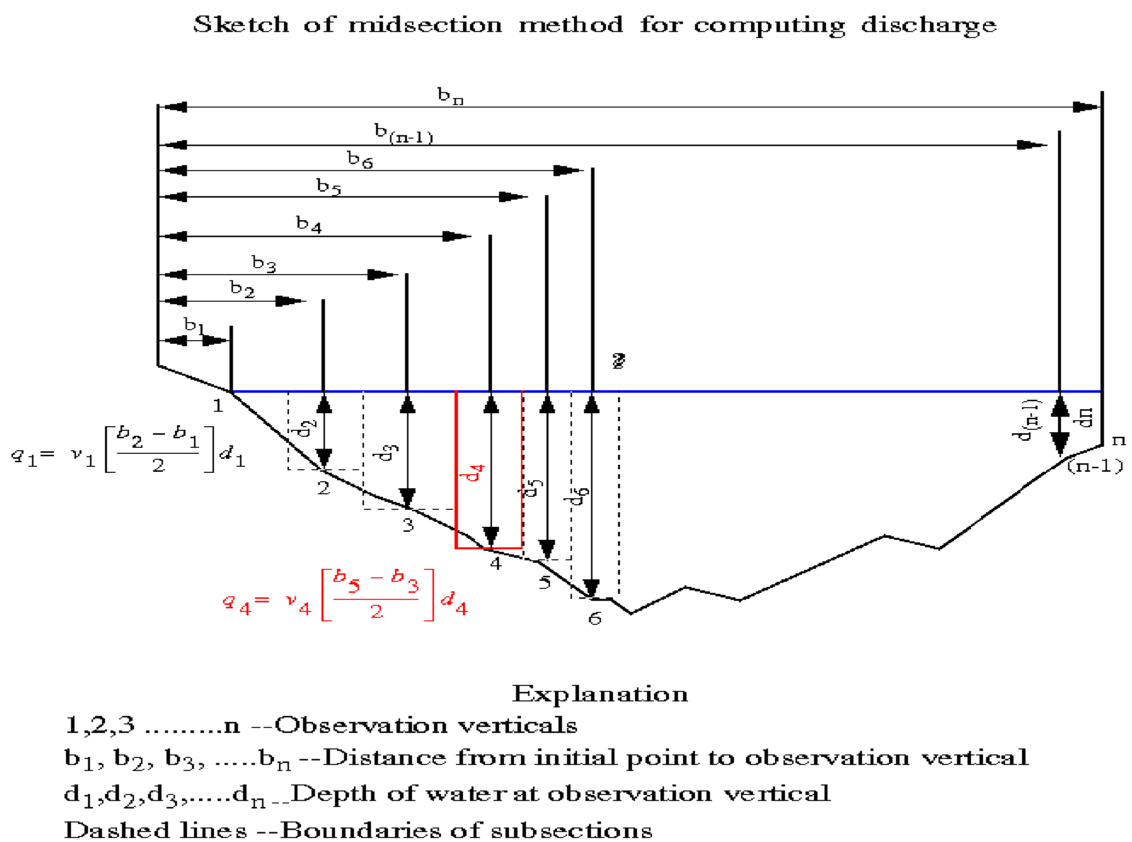

Figure 1. Midsection method sketch illustrating the theory of the procedure, from Rantz and others, 1982.

***Wadeable conditions*:** When streams are wadeable, one of two methods will be used depending on the depth at the vertical observation (d_n):

I. The six-tenths method records an observation of velocity at 0.6 of the depth below the surface when depth is less than 2.5 ft.

II. The two-point method averages velocities at 0.2 and 0.8 of the depth below the water surface when depth is equal to or greater than 2.5 ft.

1) Select a measurement cross-section of desirable qualities as previously described.

2) Stretch the measuring tape across the channel and determine the overall width of the stream.

3) Determine the spacing of the observation verticals (Figure 1) to provide about 20 subsections, spacing the verticals so that no subsection has more than 10% of the total discharge. Less than 20 subsections can be used during very low flow periods when stream widths and cross sections are small, but a subsection should never be smaller than 0.3 feet. When stream widths are less than 6 feet use as many 0.3 ft sub-sections as possible. Field personnel should decide how many subsections are practical and accurate given site-specific conditions. A general rule of thumb is to place several observation verticals in locations of rapidly changing velocity and/or depth e.g. around bridge pilings, or in eddies. Additionally, the spacing between verticals should be closer in those parts of the cross section that have the greater depths and velocities.

4) Prepare the field sheets noting the following information:
   - Name of the stream and gaging station or the exact cross-section location for a miscellaneous measurement (i.e. 300ft upstream of road crossing).
   - Date, personnel, type of meter suspension (e.g. staff or cable), and meter ID.
   - Time the measurement was started.
   - Bank of stream that was the starting point (e.g. typically left edge of water (EOW).
   - If one exists, the initial stage height and corresponding time.
   - Other pertinent information regarding the accuracy of the discharge measurement and conditions which might affect the measurement.

5) Turn on the Aquacalc computer and check the date and time on the screen. Press (0) on the Aquacalc to access the general menu. Select a transect number on the computer to record data into. Before using the Aquacalc ensure that it is set up properly for the **type of current meter being used**, the **type of measurement being made**, and to identify conditions at the measurement site. In the menus section the (Enter) key is used to skip screens and accept changes, while the (+\-) key is used to prompt an entry or toggle between choices. A detailed description of menu settings is provided in the Aquacalc manual.

6) Press (0) to exit the main menu screen and return to the measurement screen.

7) Turn off the Aquacalc and connect it to the Pygmy current meter cable with the 8 pin connector.

8) Carefully install the Pygmy current meter on the wading rod so that the cable is pointing upward and then tighten the set-screw.

9) Field-test the instrument and current meter to insure good electrical connections and proper operation. Start the cups on the current meter spinning and press (Measure). Visually count the revolutions as the cups spin down, and compare this to the revolutions reported in the Aquacalc display. Next, give the current meter a rapid spin in still air and record the time until the cups stop moving. Acceptable USGS spin test times for a Pygmy current meter should be between 30 and 90 seconds. If the meter fails to count revolutions or reported counts differ from observed counts, repeat the procedure. If a test fails again, verify the connections to the meter or see the "Troubleshooting" section in the Aquacalc manual.

10) The equipment is now ready to begin field measurements. Open the formated transect on the Aquacalc. Press (Next observe) key to move to observation #2. Entries are not recorded in observations #1 or 99.

11) At the water's edge record the horizontal distance (b_1) on the tag line and the depth (d_1) (if any). The depth determines the method of velocity measurement to be used, normally the two-point or the six-tenths depth method. Establish the recorded EOW at observation #1 on the datasheet.

12) There should be zero depth at the water's edge unless there is a wall present. . If a wall is encountered, enter the depth at the from the water's surface to the bottom of the wall.

13) Move to the next distance on the tag line. Enter the distance and depth of the stream on the datasheet.

14) Place the meter at the proper depth using the top setting rod:
    - For the two-point method set the rod at half the depth for the 0.8 measurements and 2 times the depth for the 0.2 measurements;
    - For the six-tenths method place the sensor at 0.6 depth.

15) Hold the wading rod in a vertical position with the meter parallel to the direction of flow. Field personnel should stand in a position that least affects the velocity of the water passing the current meter. For example, downstream of the tag line by half-foot, to the side of the meter by at least 1.5 ft and facing the bank. Point the meter into the current and wait for the rotation of the rotor to adjust to the speed of the current.

16) When the meter's cups are spinning and stable activate the Aquacalc measurement routine by pressing the (Measure) key. The Aquacalc will immediately start timing; counting the clicks, and displaying the running mean velocity. When the Aquacalc has satisfactorily completed its measurement, the "Measurement complete" screen will appear, showing counts, elapsed time, and velocity for the measurement. Press enter and record the velocity measurement on the datasheet.

17) If another observation at a different depth is to be made at this tag line distance, position the meter and follow the previous step for getting a velocity reading. If no more observations are to be made at the vertical, simply advance to the next tag line distance.

18) Repeat the previous steps for each vertical observation in the transect.

19) After completing the measurement at the last wet vertical station enter the ending EOW location as read on the tag line and input a depth of zero on the datasheet. To properly close a cross-section and calculate the discharge we must have an ending observation with a zero depth that represents the water's edge.

20) Upon completion of the cross-section measurements at a site, carefully remove the current meter from the wading rod and store in its case.

21) Measure and record the final stage height and review the datasheet for completeness.

Unwadeable conditions: With a few exceptions, similar procedures are used for unwadeable stream conditions as those used for wadeable conditions. The primary differences are the need to make measurements at static bridge or culvert locations, the equipment used to position the flow measuring sensor, and unique safety issues. The higher flows require measurements be made from the relative safety of a stable working surface on a bridge or culvert. The flow sensor and a sounding weight (lead fish) are suspended from a bridge or culvert rather than with a top setting wading rod. They are raised or lowered using a sounding reel connected to a counter and supported by a bridge board or portable bridge crane. The specific configuration used is dependent on the size of the weights. A different set of safety precautions will also be utilized for unwadeable conditions to reduce hazardous high-flow risks.

Since water depth is often more than 2.5 feet deep when unwadeable conditions exist, the two point method utilizing the Price U.S.G.S. type AA current meter will be used more frequently than with wadable conditions. In determining if even the two point method is adequate this criterion is used: the 0.2 depth velocity should be greater than the 0.8 depth velocity but less than twice as great (otherwise an additional 0.6 depth velocity is measured and then averaged with the average of the 0.2 and 0.8 velocities).

While bridge measurement techniques are similar to those used when making wading measurements, there are some important differences. Unlike wading measurements, velocities measured from bridges often require adjustments for horizontal angles, vertical angles, and shallow depths. Additional measuring sections may be needed at a bridge which has piers that block portions of the flow. Fewer measuring sections and velocities averaged over shorter time periods might be used during hazardous high-flow conditions or at sites where the stage changes rapidly.

The unwadeable procedures are specifically described below:

1) Record station information on measurement note sheet.

2) Measure and record stage height in the proper columns. At continuous-record site include simultaneous reading from the data logger. Record all times to the nearest minute.

3) Determine which safety requirements are warranted based on bridge walkways, traffic, weather, and stream conditions.

4) Based on current flow conditions determine which side of bridge to measure from.

5) Attach measuring tape at either end of bridge and run it out past other edge of water. During this step, form initial plan for the discharge measurement by observing the portion of the stream width which has the majority of flow. Divide this width by 20-25 to estimate approximate spacing of measuring sections. Observe the angle of flow as it passes under the bridge and the influence of bridge piers.

6) Determine the sounding weight required to measure the flow.

7) If the sounding weight is <50 lbs a bridge board can be used. If the weight is >50 lbs a bridge crane should be used.

8) Perform spin test on current meter. USGS type AA meter must spin at least 1 minute 30 seconds. A spin test will be performed at least one time every day the meter is used.

9) Assemble stream gaging equipment.

10) Turn on AquaCalc. Check date and time. Go to empty transect.

11) Enter information pertaining to gaging station, current meter, sounding weight, and cross section.

12) Enter station read from measuring tape at edge of water. Enter depth and estimated velocity if applicable.

13) Move to the location closest to the edge of water where a depth and velocity can be obtained. Enter the station from the tagline.

14) Measure depth. Lower sounding weight into water until the center of current meter bucket wheel is at the water surface. Set the outer dial on the reel to read zero. Lower the sounding weight until the weight touches the streambed. Read the outer dial on the reel and add the distance from the meter to the bottom of the weight to obtain total depth. (30 C .5, 50 C .55 or .9, 75 C and 100 C 1.0)

15) Record the depth using the AquaCalc keypad.

16) Measure velocity. Use six-tenths-depth method if depth is <2.5 ft. Use two-point (.2 & .8) method if depth is 2.5 ft or more. Using AquaCalc keypad, select which method will be used. The AquaCalc screen will display the correct depth to take a reading. Move the current meter to this depth by reading the outer dial. Press AquaCalc measure key to begin the velocity measurement. The velocity will be averaged for at least 40 seconds. While the velocity is being measured, determine if a horizontal angle or method coefficient is needed. Enter coefficients after completing the velocity measurement.

17) Move to the next station. The distance between stations should be reduced where depths and velocities are highest. Under good conditions each partial section should have no more than 5 percent of the total discharge in it but up to 10 percent is acceptable.

18) Repeat steps 14-17 until approaching the edge of water. Repeat step 13 and 12 to complete the measurement. Check to see that the current meter still spins freely. Have the AquaCalc calculate the discharge. Repeat steps 1-2. Add width, area, discharge, and descriptions of the measuring section and gaging station control to the field note sheet.

19) Disassemble equipment and return it to vehicle.

Data Management

1) Raw data is recorded on the field data sheet and the sheet is saved as a paper record.

2) Raw data is entered into the *Discharge calculations.xls* spreadsheet to calculate the summary statistics including total discharge, maximum and average velocity, maximum and average depth, and stream width and cross-section area.

3) Raw data is copied from the calculation spreadsheet and pasted to the *Discharge database.xls*; summary statistics are entered into the discharge database.

4) Summary statistics are entered into the WR database for long-term storage and analysis.

Quality Assurance:

- Equipment must be properly assembled and maintained in good condition. Avoid damage in transport by packing in appropriate cases and containers. Visual inspections of the cups and other components of the meter prior to use are essential.
- Staff are required to read equipment manuals and standard procedure's prior to training. Completion of an on-line tutorial prepared by the USGS is also recommended (http://wwwrcamnl.wr.usgs.gov/sws/fieldmethods/). Field techniques are reviewed and updated annually by Water Resource staff.
- Staff are familiar with all parts of the Price Pygmy and AA meters, understanding the overall theory and function of the device.

- Staff follow to the extent possible the guidelines for selecting an appropriate cross-section location, and current meter type.
- Staff use enough observation verticals (depth and velocity) to describe the entire cross-section, typically 20 or more observations.
- When possible, staff records stage before and after discharge measurements during times of rapid change. When stage is variable, procedures are shortened to determine a discharge rapidly, accepting the reduced accuracy.
- Staff measure depths and stage as accurately as possible. Corrections are applied following Rantz and others, 1982, for determining vertical distance if sounding weights are used from bridges.

Quality Control Requirements:

- Replicate velocity measurements are made for at least 10% of the points in a given transect.
- Replicate velocity profiles are repeated occasionally throughout the field season.
- Pre-measurement counting and spin test performance are recorded and tracked on the field data sheet or an equipment log.

General Considerations:

1) Right and left banks are defined facing downstream.
2) Water typically “pillows” at the face of the top-setting rod at high velocities; depth measurements are taken at the base of the pillow, or the surface of the water.
3) Velocity measurements are recorded to the nearest 0.01ft/second and discharge calculations are reported to the nearest $0.1ft^3$/second.
4) If depths or velocities under natural conditions are too low for a dependable current meter measurement, the cross section should be modified, if practical, to provide acceptable conditions, for example by building temporary dikes or removing rocks or debris.

Equipment Maintenance: A key concept in maintaining the accuracy of the meter is keeping it in a good condition through cleaning, adjustment, and maintenance. The meter’s manufacturer provided the following care guidelines:

- Rinse the current meter in clear water as soon as possible after use and dry using a soft cloth. The surfaces and bearings should be clear of sediment and debris.
- Never store the meter in its carrying case when wet.
- Using the oil in the case, lubricate the pivot and pivot bearing after approximately 8 hours of use, or at least once a week if used infrequently.
- Examine bearing surfaces for water, or wear or damage, especially the pivot point. The pivot should feel sharp and not contain any burs or marks.
- To avoid damage to the pivot and pivot bearing, be sure to replace the pivot with the brass-shipping pivot when the meter is not in use.

References:

Fulford, J.M., 2001. Accuracy and consistency of water-current meters. Journal of the American Water Resources Association, Vol. 37 (5): 1215-1224.

Rantz, SE, and others, 1982. Measurement and computation of streamflow: Volume 1, Measurement of stage and discharge: USGS Water Supply Paper 2175.

Rantz, SE, and others, 1982. Measurement and computation of streamflow: Volume 2, Computation and discharge: USGS Water Supply Paper 2175.

Instruction Manual. Aquacalc 5000 Advanced Stream Flow Computer, Operating Instructions. JBS Instruments, West Sacramento California.

APPENDIX C: Discharge Measurement Checklist (Wadeable Conditions)

Discharge measurement checklist

Equipment
Pygmy current meter
AquaCalc computer
top-setting rod (with AquaCalc mounting bracket)
100' fiberglass measuring tape (weighted)
safety rope (if high water conditions)
lifejacket (if high water conditions)
rebar stakes (2) and hand sledge
surveyor's measuring rod (optional)
stream discharge datasheets and clipboard
wading boots/chest waders
tool box (blue)
small Action Packer kit*
cell phone
rain gear (if necessary)
machete
M-1 key

*Action Packer kit includes:
digital camera
spare pens/pencils
DI water
1-L sample bottle
spare sample bottle sets (2)
county atlas
clipboard
pH 7 and 10 buffer
chem-wipes
soap
hand-wipes
spare field notebook
spare 9v batteries
tape
zip ties

APPENDIX D: Stream Discharge Measurement Datasheet

Basin/Sub Basin: ____________________

Site ID: ____________________ Personnel: ____________________

Date/Time: ____________________

Meter Type: ____________________ Meter S/N: ____________________

Stage Location: ____________________ $Stage_o$ (ft): ____________________

____________________ $Stage_f$ (ft): ____________________

Starting Bank (left or right): ____________________ ____________________

Transect #: ____________________ Estimated Q: ____________________

Basic tasks to complete:

1. Select an acceptable measurement cross section.
2. Measure the initial stage.
3. Set-up the tag line perpendicular to the general flow and estimate the average depth for selecting the current meter.
4. Determine the approximate spacing of the observation verticals.
5. Prepare the field sheets and enter the settings into the Aquacalc computer.
6. Assemble the equipment and perform the field tests.
7. Determine the depth and velocity at the observation verticals.
8. Calculate the discharge and edit/recalculate the transect if necessary.
9. Measure the final stage.
10. Disassemble and store the current meter.

Stream Width: ____________ **Velocity Max:** ____________ **Stream Depth Max:** ____________

X-section area: ____________ **Velocity Ave:** ____________ **Stream Depth Ave:** ____________

Total Q: ____________

Obs.	Tape (ft)	Depth (ft)	Velocity (ft/s)		
			Top	Mid	Bottom
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					
21					
22					
23					
24					
25					

QC Requirements

Is the meter functioning properly?

____

____

Replicates:

	Obs.	Tape	Depth	Velocity
Rep1				
Rep2				
Rep3				
Rep4				

Comments/Sketches:

APPENDIX E:
Example Certificate of Calibration for
WaterLog Series DH-21 Stage and Temperature Sensor

COUGAR CR.

WATERLOG® SERIES Environmental Products A Division of Design Analysis Associates, Inc.

Certificate of Calibration

This certifies that your precision instrument met all of the specifications determined by tests performed on the date listed below. This instrument was subjected to extensive pre-qualifications. It was then calibrated using an automated test system over a period of approximately 20 hours followed by another 20 hour validation test.

H_2OFX calibration standards are traceable to the National Institute of Standards (NIST). The Model Number and Serial Number of the standard used are listed below.

The test data below is a sampling of the 150 actual data points taken during the pre-shipment validation test on this instrument.

Tested by

TEST REPORT

REPORT DATE: 3/20/2003
DATE TESTED: 3/18/2003
MODEL NUMBER: WaterLOG DH-21
SERIAL NUMBER: S#01845
NIST TRACEABLE REFERENCE: DH Instruments Model RPM1-G0015 SN43379

REFERENCE TEMP.	MEASURED TEMP.	REFERENCE PRESS.	MEASURED PRESS.	DELTA
-5.1	-5.0	0.000	0.000	0.000
-5.0	-5.0	2.239	2.239	0.000
-5.1	-5.0	4.485	4.485	0.000
-5.0	-5.0	8.995	8.995	0.000
-5.0	-5.0	13.491	13.491	0.000
-0.1	-0.1	0.743	0.743	0.000
0.0	0.0	2.990	2.991	-0.001
-0.1	-0.1	5.985	5.985	0.000
-0.1	0.0	10.475	10.476	-0.001

S#01845